The Differential Association Between Affect and Sleep in Adolescents With and Without FGIDs

By

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Abstract

Background: Children and adolescents with chronic abdominal pain experience more disruptions to their daily living than their healthy same-aged peers. Adolescents experiencing chronic pain associated with Functional Gastrointestinal Disorders (FGIDs) suffer negative impacts on their health behaviors (i.e., sleep) and are also at risk for a range of problems related to negative affect such as subclinical symptoms of depression and symptoms of anxiety, which may serve to exacerbate one another in a reciprocal fashion. The aim of the study was to determine if the strength of the relationship between affect and sleep differs across healthy adolescents and a chronic abdominal pain group.

Methods: Twenty-five adolescents with FGIDs were compared to 25 of their same-aged peers to examine the differential association between affect and total sleep time (TST). This study utilized ecological momentary assessment surveys and objective assessments of sleep to capture intensive longitudinal data for both groups. Data analysis included both between- and within-person variables examined using multilevel models.

Results: Results from the group comparison analysis revealed that adolescents in the FGID group reported significantly lower quality of life than their same-aged peers. The results of the multilevel models revealed that TST was associated with group status ($\beta = 31.35$, $p < .05$), indicating that community adolescents exhibited longer sleep duration than the adolescents with an FGID. Models predicting TST revealed a significant 3-way interaction between weekday, group status, and negative affect ($\beta = 26.27$, $p < .05$). Simple slopes analysis indicated that when negative affect is one standard deviation below the child's own average on weekends, participants in the FGID group obtained significantly more sleep than those in the comparison group ($\beta = 47.67$, $p < .05$).

Conclusions: The adolescents with FGIDs in the present study reported significantly lower quality of life on both the psychosocial and school subscales, indicating quality of life may be reduced when there is emotional distress regarding school issues. The findings of the present study show that when adolescents with FGIDs have lower emotional distress, or negative affect, on the weekend when demands are reduced, they are able to obtain longer sleep durations. These findings confirm that unique relationships exist between negative affect and sleep duration for youth with FGIDs, and the interaction of these variables on weekend days may hold value in understanding and addressing these potential targets in treatment.

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Introduction

The Bidirectional Relationship Between Sleep and Affect

The link between sleep behaviors and mood has been observed in healthy populations of children and adolescents (Fuligni & Hardway, 2006; Wolfson & Carskadon, 1998). Poor sleep can negatively impact emotional well-being the following day (Franzen, Siegle, & Buysse, 2008), and negative emotions can compromise sleep quality and increase sleep disturbances (Murray, Murphy, Palermo, & Clarke, 2012). Periods of extremely high positive affect can disrupt sleep onset and account for shorter sleep durations (Hechtman, Raila, Chiao, & Gruber, 2013) and positive affect has been shown to decrease after a period of significant sleep loss in healthy children and adolescents (Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010). Adolescents who spend less time sleeping on a typical day tend to report elevated negative and diminished positive daily affect on average (Fuligni & Hardway, 2006), and feelings of more tension, anger, anxiety, and negative affect has been reported by youth with restricted sleep schedules (Baum et al., 2014; Kahn, Sheppes, & Sadeh, 2013).Further, emotional and behavioral problems are elevated for adolescents who have shorter sleep durations on weekdays (O'Brien & Mindell, 2005).

To capture the processes underlying this relationship, it has been suggested that sleep and affect are influenced by "emotional brain networks" (Kahn et al., 2013). Sleep loss can lead to changes in emotion processing and thus affect higher order cognitive process including memory, judgment, and decision-making (Killgore, 2010). Since sleep loss can disrupt these functions of the prefrontal cortex, it has been hypothesized that these disruptions lead to difficulty inhibiting and exercising control over negative emotions (Dahl & Lewin, 2002) because nighttime sleep

has been shown to consolidate memories in an emotionally adaptive way (Walker & van Der Helm, 2009). If sleep is disrupted, the emotional content within memories may not be fully encoded and consolidated, and can lead to a higher emotional response to situations that may influence mood the following day. Given that adolescents report elevated emotional problems when they obtain less sleep on weekdays (O'Brien & Mindell, 2005), it may be important to examine the difference between weekdays and weekend days. Since adolescents tend to report two additional hours of sleep on the weekends (Wolfson & Carskadon, 1998), the relationship between sleep duration and affect may differ between these structured and unstructured days.

Sleep, Inflammation, and Chronic Pain

While sleep is important for all adolescents in maintaining positive mood states, there is a growing body of literature that indicates sleep disturbances can be particularly harmful in exacerbating pain and inflammation in youth with chronic pain (Bromberg, Connelly, Anthony, Gil, & Schanberg, 2016; Long, Krishnamurthy, & Palermo, 2008; Valrie, Bromberg, Palermo, & Schanberg, 2013). Sleep disturbances can negatively impact disease symptoms, such as pain and fatigue, and decrease quality of life (Ranjbaran, Keefer, Stepanski, Farhadi, & Keshavarzian, 2007). Further, there is support for a bidirectional relationship between sleep and immune system function (Ali, Choe, Awab, Wagener, & Orr, 2013; Motivala & Irwin, 2007). When a person's immune system is activated via acute inflammation and infection, their typical sleep habits can be altered. Conversely, abnormal sleep behaviors can affect one's immune system function (Ranjbaran et al., 2007), and ultimately lead to systematic inflammation with increased symptoms of pain (Valrie et al., 2013). During a typical circadian rhythm, the production of pro-inflammatory cytokines peak during sleep periods and initiate an adaptive immune response during the day through the regulation of anti-inflammatory signals (Kinnucan, Rubin, & Ali,

2013; Lange, Dimitrov, & Born, 2010; Zee & Turek, 2006). When one's sleep behaviors are atypical they can accumulate "sleep debt" leading to allosteric load and compromised immune function (Lange et al., 2010; Luyster, Strollo, Zee, & Walsh, 2012).

For adolescents with chronic pain conditions, consistent sleep is important for their overall health and symptom expression. Sleep plays a protective role, and when sleep is significantly disrupted, the immune system is susceptible to infection (Ali et al., 2013) and can hinder the body's ability to combat pathogens (Motivala & Irwin, 2007). This is particularly problematic for youth with chronic pain because sleep disturbances are more frequent in pediatric pain populations compared to their healthy peers (Lewandowski, Ward, & Palermo, 2011). Adolescents with chronic pain display more symptoms of insomnia (Palermo, Law, Churchill, & Walker, 2012), lower sleep efficiency, more nightly awakenings (Palermo, Toliver-Sokol, Fonareva, & Koh, 2007), and are more likely to assess their perceived sleep quality as poor, compared to their healthy peers (Fales, Palermo, Law, & Wilson, 2015). Further, poor sleep quality has been linked in a bidirectional relationship with reported pain for adolescents who experience persistent pain (Valrie et al., 2013). Some treatment recommendations for chronic pain have suggested evaluating and treating sleep disorders in patients with gastrointestinal disorders (Ali et al., 2013), and mention sleep as a factor to manage in chronic inflammatory conditions (Ranjbaran et al., 2007).

Functional Gastrointestinal Disorders

There is a subpopulation of disorders within the chronic abdominal pain category, called functional gastrointestinal disorders (FGIDs; i.e., functional dyspepsia, irritable bowel syndrome, and/or functional abdominal pain syndrome) or disorders of the gut-brain interaction (Schmulson & Drossman, 2017). Children and adolescents with these disorders experience continuous or

periodic abdominal pain, which influences daily functioning and is associated with emotional and physical distress relative to healthy peers (McOmber & Shulman, 2008). Among chronic pain populations seeking care in specialty practices, FGIDs are some of the most common gastrointestinal disorders diagnosed (Chang, 2004). Further, the symptoms adolescents experience as a result of chronic pain can lead to high healthcare utilization and economic burden (Groenewald, Essner, Wright, Fesinmeyer, & Palermo, 2014).

The term "chronic abdominal pain" is a broad symptom category that can be attributed to many different diseases, and therefore requires further specification when discussing a population who exhibit this symptom. Before there was greater understanding of FGIDs, the term "recurrent abdominal pain (RAP)" was historically used to describe persistent abdominal pain with no clear etiology under the traditional biomedical model (Apley, 1975; Apley & Hale, 1973; Apley & Naish, 1958). Over the past four decades, there has been a shift in the way diseases are conceptualized and the idea that symptoms could be influenced by environmental and psychosocial influences took root through the biopsychosocial model (Drossman, 2006). In an effort to legitimize these disorders with unclear etiology, the Rome classification system was introduced in the early 1990s, which led to RAP being modified and subdivided into more defined, separate disease groups under the umbrella term "Functional Gastrointestinal Disorders" (Drossman, 2003). The term "functional" is used to describe symptoms that may accompany normal development or symptoms that are not caused by organic diseases (i.e., no structural or biochemical abnormalities, or underlying pathophysiology). The Rome classification system has since been revised multiple times; with the most recent version published in 2016. Through each iteration of the Rome diagnostic criteria, attempts have been made to subdivide the diagnosis of these diseases into meaningful distinctions for higher reliability in diagnosis. The current Rome

IV criteria has placed greater emphasis on the "brain-gut" interaction (i.e., abnormal motility, altered mucosal immunity, or visceral hypersensitivity) and how this process influences the expression of the FGID.

FGIDs are classified by various gastrointestinal symptoms that are not due to any structural or chemical abnormality (Gieteling, Bierma-Zeinstra, Passchier, & Berger, 2008; Rasquin et al., 2006). Rather, muscles and nerves are either uncoordinated, or the way in which the brain interprets sensitivity to the GI nerves is impaired (Jones, Dilley, Drossman, & Crowells, 2006). Further, psychosocial variables can interact with altered gut physiology along the brain-gut axis to influence symptoms of FGIDs. Internal triggers (i.e., stress and anxiety) can interact with external triggers (i.e., microbes and allergens) and may activate an inflammatory response, such as mast cells and eosinophils (Friesen, Schurman, Colombo, & Abdel-Rahman, 2013). Inflammation can then impact visceral hypersensitivity for individuals with FGIDs. Management of these disorders can be complex due to physiological and psychological dysregulation impacting symptom expression, and lack of a clear roadmap in the form of clinical practice guidelines (McOmber & Shulman, 2008).

Biopsychosocial Model

FGIDs are commonly conceptualized as having a biopsychosocial etiology and process. This model explicitly states both biological and psychological predispositions can influence the expression of disease and illness (Drossman, 1998; Engel, 1989). Under this framework, intra- and interpersonal functioning is considered across physical, psychological, and environmental factors (Segal-Andrews, Altschuler, & Harkness, 1995) to better understand how they influence chronic abdominal pain symptoms. FGIDs are a unique and difficult to treat phenomenon because there are very clear pain symptoms that do not reduce down to a clear organic etiology.

What is observed, however, is a highly individualized pain profile both in terms of triggers for pain, and with regard to how frequent or intense a given patient's pain symptoms will be perceived on a given day (Drossman, 2006; McOmber & Shulman, 2008). When examining an individual child's pain experience, physicians and clinicians must consider numerous biological, individual, family, psychological, and community factors to understand how each relationship impacts symptom expression.

Given the pain, school disruption, and distress that commonly accompany FGIDs, it is unsurprising that children and adolescents with FGIDs self- report significantly lower overall quality of life than their healthy peers and other youth with organic GI disorders (Varni et al., 2015). When quality of life domain scores are examined at the subscale level (i.e., physical, emotional, social, and school), youth with FGIDs report lower quality of life scores on all dimensions (Varni et al., 2015; Youssef, Murphy, Langseder, & Rosh, 2006). In some cases, problems with negative affect may rise to a clinical level as youth experiencing chronic abdominal pain as part of FGIDs are more likely to receive a diagnosis of anxiety or depression compared to their healthy peers (Campo et al., 2004; Cunningham et al., 2013). Given the biopsychosocial framework, this may be problematic because such declines in mood can increase pain and lower quality of life in youth with FGIDs (Varni et al., 2015; Waters, Schilpzand, Bell, Walker, & Baber, 2013) and mood states have been shown to impact sleep behaviors further influencing pain.

Sleep Disruptions in Pediatric FGIDs

Adolescents with FGIDs, on average, have increased difficulty initiating sleep, more difficulty maintaining sleep, have more distressing thoughts regarding pain at bedtime, and have poorer perceived sleep quality compared to their healthy peers (Haim et al., 2004; Huntley,

Campo, Dahl, Lewin, 2007). This is problematic because extended periods of wakefulness have been shown to increase symptoms related to pain in children with FGIDs (Schurman & Friesen, 2015). Further, adolescents with FGIDs are particularly at risk for increased pain since they are more likely to have difficulty falling asleep than younger children with chronic pain (Schurman et al., 2012).

It is currently unclear whether FGID patients experience more disruption in their mood following a night of poor sleep compared to their healthy peers. This is important because recent work has indicated that patients with FGIDs experience more pain when sleep is disrupted and when negative affect is higher than usual (Schurman & Friesen, 2015). Therefore, if a patient with an FGID experiences disrupted sleep they may experience a corresponding increase in negative affect, and both of these changes are undesirable, as they have been linked to increases in pain.

The Present Study

The purpose of this study is to compare a sample of adolescents with FGIDs to a sample of their same-aged peers across quality of life, positive and negative affect, and sleep duration. Measures of daily affect and sleep duration, or total sleep time (TST), were collected in the adolescent's free-living environment to measure intra- and inter-personal differences. Ultimately, this study examined the relationship between sleep duration and affect in each sample to understand the differential relationship between adolescents with and without chronic abdominal pain. Given the group differences observed in youth with chronic abdominal pain and their healthy peers, youth diagnosed with an FGID are expected to experience more disruption in psychosocial variables associated with sleep, such as affect, more intensely than their healthy peers.

The first aim was to compare the sample of adolescents with an FGID to a sample of their same-aged peers on quality of life, positive affect, negative affect, and TST for descriptive purposes as these hypotheses have been tested in the research literature. The following hypotheses address this aim: 1) adolescents with FGIDs will report lower quality of life than their same-aged peers, 2) adolescents with FGIDs will report less positive affect than their same-aged peers, 3) adolescents with FGIDs will report higher negative affect than their same-aged peers, and 4) adolescents with FGIDs will display shorter sleep duration than their same-aged peers. The first aim utilizes person-level means for the repeated measure variables (i.e., positive affect, negative affect, and TST).

The second aim was to examine the potential differential association between negative affect and TST in adolescents with an FGID and their same-aged peers with group status acting as the moderator. It was hypothesized that as an aggregate effect for all adolescents, shorter sleep duration will be associated with more negative affect and group membership will moderate the association between TST and negative affect (Figure 1). It is expected that the slope of the relationship between TST and negative affect for adolescents with FGIDs will be will be steeper, compared to their healthy peers. Further, a dichotomous weekend/weekday variable will be entered into the model as an exploratory moderator and adolescents are expected to show longer sleep durations on the weekends.

The third aim was to examine the potential differential association between positive affect and TST in adolescents with an FGID and their same aged-peers with group status acting as the moderator. It was hypothesized that, as an aggregate effect for all adolescents, longer sleep duration would be associated with more positive affect, and group membership will moderate the association between TST and positive affect (Figure 1). This exploratory hypothesis will assess

for differences in the slope of the association between TST and positive affect in both samples. Further, a dichotomous weekend/weekday variable will be entered into the model as an exploratory moderator and adolescents are expected to show longer sleep durations on the weekends.

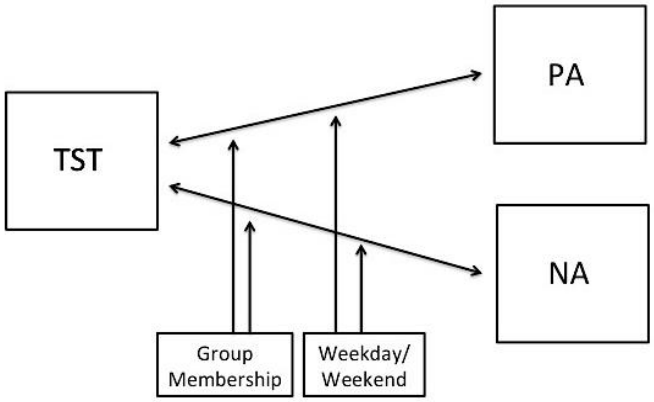

Figure 1: Model of the bidirectional associations tested in Aim 2 and 3 with level 2 moderators.

Methods

The full sample of this study encompassed participants from two distinct studies. The adolescents with FGIDs are part of the Precision Medicine in Pediatric FGIDs study. This is a collaboration between the Children's Mercy Hospital Abdominal Pain Clinic and the University of Kansas Pediatric Health Insight Team Lab. The community adolescents are part of the Affect Health and Behavior Study (AHAB), a University of Kansas Pediatric Health Insight Team Lab project. The participants in each study completed similar protocols with overlapping measures.

Participants

A subsample of twenty-five adolescents were selected from the full samples of adolescents recruited from the Pediatric Gastroenterology Clinic and the AHAB study. The full

sample of participants for this study consisted of 50 adolescents aged 13 to 17 years old (M = 14.92, SD = 1.40). Each participant with an FGID was matched with an AHAB participant based on demographic information (age, sex, family income, and ethnic background). This was done to compare both samples on the outcomes of interest and limit the influence of confounding variables. Each sample and set of study procedures are presented separately to reflect the distinct aspects of the larger Precision Medicine in Pediatric FGIDs study and AHAB study.

Adolescents with chronic abdominal pain. Sixty adolescents with a functional gastrointestinal disorder were recruited from a multidisciplinary Pediatric Gastroenterology Clinic located at a local Children's Hospital during their initial evaluation appointment. A research assistant approached children and adolescents between the ages of 8 and 17 in the Pediatric Gastroenterology Clinic for participation. Eligibility criteria for participation included: 1) the ability to read at grade level in English, 2) have no significant visual impairment, 3) have no physical disabilities that would limit mobility, 4) have a diagnosis of a functional gastrointestinal disorder associated with abdominal pain based on the Rome III criteria (Rasquin et al., 2006), and 5) experience pain at least twice a week at the time of enrollment. Although participants below the age of 13 were recruited for the Precision Medicine in Pediatric FGIDs study, only participants between the ages of 13 and 17 were used for this project to allow for matching with the comparison sample.

Community adolescents. One hundred adolescents from a Mid-west community were recruited to participate in the AHAB study. To recruit these participants, flyers were posted throughout the community, and research assistants attended community events to provide study information to interested adolescents. Eligibility criteria for participation included: 1) must be between 13 and 18 years old, 2) have the ability to read and write at grade level in English, 3)

have no physical disabilities that would limit mobility, and 4) have no significant visual impairment that would impede using a smartphone. Participants from the AHAB study who are over the age of 17 were not used in this project in order to match participants by age.

Procedure

The protocols and study materials used in this research project were submitted to an Institutional Review Board (IRB) before either sample was approached for recruitment. The Precision Medicine in Pediatric FGIDs study was approved by the IRB at Children's Mercy Hospital and the AHAB study was approved by the IRB at the University of Kansas. Similar protocols were utilized for the sample of adolescents with and without chronic abdominal pain, and the measures used in data analysis were the same for all participants.

Adolescents with FGIDs. For the adolescents recruited at the Pediatric Gastroenterology Clinic, an on-site research assistant approached eligible adolescents as part of their new patient visit. If the adolescents with an FGID and their guardian were interested, the research assistant completed parental consent and adolescent assent with the family. The adolescent then completed baseline questionnaires on a computer. After the questionnaires were completed, the research assistant demonstrated how to use the accelerometer and identified four times the participant could answer surveys throughout the day (i.e., morning, early afternoon, evening, and before bed). Once the survey times were programed on the phone app, the research assistant showed the participants how to use the smartphone and answer the surveys. The smartphone app administered an ecological momentary assessment survey four times a day, over the course of 14-days. The participants were instructed to continuously wear the accelerometer on their non-dominant wrist for the entire study period. The research assistant contacted the participant after the first few days to check if they had any questions. The participants with an FGID were

instructed to mail the study equipment to the study team using a prepaid box. They filled out their final study measures when they returned for their next clinic visit as part of their standard of care.

Community adolescents. Interested adolescents contacted the Pediatric Health Insight Team. A research assistant screened the adolescent over the phone to ensure they were eligible to participate in the study. If the adolescent was eligible for participation, a baseline visit was scheduled at the Pediatric Health Insight Team Lab, located at the University of Kansas. The adolescent was informed that a parent or legal guardian must accompany them to the visit in order for them to consent for research.

When the adolescent arrived to the lab for their baseline visit, their legal guardian provided consent for them to participate in the research study, and the adolescent provided assent for research participation. Adolescents filled out demographic information with their parents and then filled out the baseline measures at a computer. While the adolescent was completing the computer-based measures, the research assistant initialized the study devices (i.e., accelerometer) and prepared the surveys to be loaded on a smartphone to be provided to the adolescent for the duration of the study. Once the measures were completed, the participant was trained to use the smartphone app and shown how to properly wear the accelerometer. Participants were instructed to wear the accelerometer on their non-dominant wrist continuously for 20 days from the initial study visit until the morning after the last daily survey has been administered. Consistent with previous protocols (Brannon, Cushing, Crick, & Mitchell, 2016), participants indicated the time of day (i.e., morning, early afternoon, evening, and before bed) they were available to answer the survey on the smartphone. The research assistant then programed the surveys into the

smartphone app and demonstrated how the app functioned. The smartphone app administered an ecological momentary assessment survey four times a day, over the course of 20 days.

Ecological momentary assessment surveys took approximately 3-5 minutes to complete. An alarm sounded when it was time for the participant to answer the survey and did not cease until the participant answered the first survey question. All other functions on the smartphone were disabled. The research assistant called the adolescent during the first few days of their participation to check if the devices were working properly and to see if they have any questions. After their completion of study participation, the community sample of adolescents returned to the research lab for an exit visit to return study equipment and fill out the final study measures. For the purposes of this study, the last six days of accelerometer and survey data were removed from the dataset. The first 14 days of accelerometer and survey data were retained for the community adolescents for the present study. This was done to make the study window the same as the FGID sample.

Participants in both protocols were compensated for study involvement and had the opportunity to earn up to $40 if they answered at least 80% of the surveys, wore the accelerometer at least 80% of the study days, and wore an additional device that measured heart rate which was not included for the purposes of this study. The measures used in the analysis were the same for all participants, despite the protocols for each study being slightly different. The 14-day study protocol involving adolescents with chronic abdominal pain was compared to the first 14 days of the protocol involving the community adolescents. It is appropriate to compare 14-days of one study to 14-days of another because all participants filled out the same measures and followed the same study protocol for the two-week period.

Smartphone App. Each participant was provided an Android smartphone preloaded with the surveys on the PETE application (Brannon et al., 2016). This tool was developed to administer ecological momentary assessment (EMA) surveys to measure various processes that change within an individual at designated times throughout the day. The smartphone stored the participant data and was downloaded when the phone was returned to the research lab. Surveys were administered four times a day for 14-days, leading to 56 potential observations altogether, per person.

Measures

Sleep Duration. The Actigraph GT3X+ accelerometer was used to obtain an objective measure of sleep duration throughout the study period. This tool is a validated wireless tri-axial activity monitor, and provides valid estimates of sleep time when worn on a person's non-dominate wrist. The device is waterproof and does not require charging during the study period. Raw data was processed using Actilife software v.6.10.2, and scored using the algorithm developed by Sadeh and colleagues (Sadeh, Sharkey, & Carskadon, 1994) to estimate sleep duration, or TST.

Demographics. Participants were asked to provide demographic information at the initial study visit with their parents. Information regarding the child included age, sex, ethnicity, family income are located in Table 1.

Table 1

Demographic Characteristics of Participants and their Families

Demographic Variable	n=50	%		
Gender				
Male	6	12		
Female	44	88		
Race/Ethnicity				
Caucasian	46	92		
African American	0	0		
Hispanic/Latino	0	0		
Asian	0	0		
Other/Multiracial	2	4		
Not Reported	2	4		
Approximate Family Income				
< $10,000	0	0		
$10,000-$30,000	12	24		
$31,000-$50,000	8	16		
$51,000-$70,000	12	24		
> $70,000	18	36		
			M	*SD*
Adolescent Age			14.92	1.40

Note. *M* = mean; *SD* = standard deviation.

Quality of Life (QOL). Adolescents filled out the Pediatric Quality of Life Inventory Version 4.0 (PedsQL), a health-related quality of life measure, at their Baseline study visit. The PedsQL is a 23-item questionnaire that measures self-reported QOL designed to assess how much each item has been a problem for the adolescent in the last month (Varni, Burwinkle, Seid, & Skarr, 2003). The PedsQL measure is a well-validated and reliable measure consistently used to assess QoL in pediatric populations (Palermo, Fonareva, & Janosy, 2008; Youssef et al., 2006). This measure demonstrated good overall reliability in this sample ($\alpha = .83$). The PedsQL uses an ordinal scale with anchors of never, almost never, sometimes, often, and almost always (scored 0 to 4). Raw scores were recoded and calculated into a total score, ranging from 0-100, with higher scores indicating higher perceived quality of life. The measure is broken down into four domains: Physical Functioning, Emotional Functioning, Social Functioning, Psychosocial

Functioning, and School Functioning. Further, each subscale demonstrated acceptable reliability ($\alpha = .67$, $\alpha = .70$, $\alpha = .71$, $\alpha = .75$, $\alpha = .76$, respectively).

Affect. Adolescent positive and negative affect was measured via the Positive and Negative Affect Schedule (PANAS)-Child Version, a measure which has demonstrated good reliability and validity in youth (Laurent et al., 1999). Participants were asked to rate the extent to which they currently felt an emotion using a 5-point rating scale ranging from "not at all" to "extremely" (e.g., How happy are you feeling right now?). Ten items were chosen from the PANAS to use in the EMA surveys, five items with the highest factor loading from the positive affect subscale (i.e., joyful, cheerful, happy, lively, and proud) and five items with the highest factor loading from the negative affect subscale (i.e., miserable, mad, afraid, scared, and sad). Each affect subscale was designed to assess a mixture of self-report valence and arousal. A mean total score was calculated for both positive and negative affect based on the corresponding items for each scale. Both positive affect and negative affect demonstrated good reliability in this sample ($\alpha = .90$, $\alpha = .82$, respectively). These questions were administered four times a day, however, in order to analyze these constructs with TST, a variable at the day level, each affect observation was aggregated over each day. The day level positive affect and negative affect variable was used in the multilevel analyses in Aim 2 and 3.

Data Analysis Plan

To address the first aim, an Analysis of Variance (ANOVA) was conducted to examine the differences between groups on quality of life, positive affect, negative affect, and TST. The ANOVA test determined if the mean difference on a continuous dependent variable is statistically different between two discrete groups. This level of analysis utilized person-level means for the repeated measure variables (i.e., positive affect, negative affect, and TST).

Data Screening. To prepare the data to address aims 2 and 3, data were screened for invariant responding (e.g., all EMA items answered with the same value). Of the expected EMA observations, 89% were fully completed by study participants. The data were screened for invalid responses and 3% of cases were dropped from the dataset due to participants indicating the same integer across the affect variables. Of the surveys completed, participants answered all questions in approximately 3 minutes, on average. If a participant took longer than 7 minutes to complete the survey (2 standard deviations above the mean) then that observation was not included in the final dataset. In addition, past protocols have demonstrated that participants will sometimes continue to complete surveys after the study period, but before devices have been returned. These cases were also dropped from the final dataset.

Missing Data. Similar protocols have yielded a high rate of compliance and complete data (Brannon et al., 2016), however small amounts of missing data were expected to occur. Missing data was handled using full information maximum likelihood estimation (Enders, 2001) with the assumption that data are missing at random. Through this estimation, the missing responses are skipped over and the actual responses are assumed to be representative of the overall shape of the dimensions included in the model. This estimator assumes missing values on a given variable are conditionally dependent on other observed variables in the data, and incorporating vectors of partially complete data in the individual-level likelihood functions implies probable values for the missing data during the parameter estimation process (Enders, 2001). This method directly estimates model parameters and standard errors using all available raw data and is a preferred way for estimating missing data since this approach introduces less bias when estimating the parameters.

Centering Predictor Variables. The intensive longitudinal data in the current study had two sources of variability. Specifically, there was between-person variance (i.e., the variability of responses across participants) and within-person variance (i.e., the variability of an individual's responses over time). To model these two sources of variability, independent variables were both grand mean and person mean centered. First, independent variables had the grand mean subtracted from each observation. The grand mean centered variable was then aggregated within each participant to form the between-person variable. Finally, the between person variable was subtracted from each observation to form the within-person variable. The between- and within-person variables were entered into a bivariate correlation matrix, and each was shown to be orthogonal. This is to be expected since each variable represents either between-person or within-persona variability and would not be correlated.

Model for Time. The longitudinal nature of the data creates the possibility that the dependent variable in each model may change over the course of the study, and that this change may differ across participants. Time was entered as a linear, random linear, quadratic, and random quadratic predictor in four separate models, to explicitly test for the influence of time. Nested model comparisons were conducted to determine which effect of time was most representative of the data.

Substantive Models. Separate models were fit to examine positive and negative affect as predictors of sleep duration. To evaluate a potential bidirectional relationship sleep duration was also examined as a predictor of positive and negative affect. Each independent variable was also evaluated for the presence of a random effect. This test involved a nested model comparison against the initial model with no random effect. The best fitting model was determined by comparing the -2 log likelihood (-2LL) value of each model, with lower values indicating better

model fit. If there was a significant difference in the -2LL values of two separate models based on a chi square difference test, the one with the smaller value was retained and interpreted as the final model. Group membership (e.g., sample with chronic abdominal pain or community sample) was used as a dichotomous variable and was tested as a moderator in the relationship between sleep and affect. In addition, a dichotomous weekday/weekend variable was tested as an additional moderator in this relationship. This weekday/weekend variable coded the days in which participants would have limited opportunities to sleep in (i.e., Monday, Tuesday, Wednesday, Thursday, and Friday) as weekdays. Days in which participants would have increased opportunity to sleep in (i.e., Saturday and Sunday) were coded as weekends. This variable corresponded with the day the adolescent woke up for each TST observation.

Probing significant moderators. If significant interactions are found the region of significance was determined to examine how sleep duration and affect vary as a function of the moderators. The region of significance is importance to assess within an interaction, because this describes the specific values of the moderator at which the slope of the regression line between the outcome and focal predictor transition from non-significance to significance (Preacher, Curran, & Bauer, 2006).

Results

Descriptive Statistics

Descriptive statistics for TST, quality of life, positive affect, and negative affect are presented in Table 2. The mean, standard deviation, and range are presented for each measure, and for the total sample and for the FGID and comparison groups. While a measure of pain was outside the scope of the present study analysis, the adolescents with FGIDs reported an average pain intensity score of 2.67 (*SD* = 1.34) on a scale of one to five.

Table 2

Descriptive Statistics for Total Sample and Each Group

Measure	Total Sample		Community Adolescents		Adolescents with FGIDs	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Total Sleep Time	420.64 (90.06)	178-785	411.29 (74.39)	213-559	430.34 (103.01)	178-785
Quality of Life						
Total Score	72.28 (12.60)	44.05-96.59	76.27 (12.51)	47.73-96.59	68.12 (11.51)	44.05-88.64
Physical	76.47 (13.93)	34.38-100	79.00 (14.42)	46.88-100	73.83 (13.19)	34.38-90.63
Emotional	65.92 (17.22)	40-100	66.00 (17.62)	40-100	65.83 (17.17)	45-100
Social	75.64 (19.85)	31.25-100	82.50 (18.04)	50-100	68.49 (19.46)	31.25-100
School	69.26 (18.71)	40-100	77.20 (16.96)	45-100	60.99 (17.06)	40-100
Psychosocial	69.90 (14.08)	46.43-96.43	74.71 (13.84)	48.21-69.43	64.88 (12.74)	46.43-89.29
Positive Affect	4.89 (2.56)	0-12	5.77 (2.44)	0-12	3.99 (2.36)	0-11
Negative Affect	1.48 (1.70)	0-8	1.38 (1.44)	0-7	1.59 (1.92)	0-8

Aim 1: Adolescents with an FGID were compared to a sample of their same-aged peers on quality of life, positive affect, negative affect, and sleep duration.

ANOVAs were performed with FGID or comparison group membership as the grouping variable. One of the participants in the FGID group did not complete the QoL questionnaire. Thus, the results of these analyses are based on 49 participants. Regarding QoL, there was a significant difference and large effect size between groups on the total score (d = 0.68), on the social scale (d = 0.74), the psychosocial scale (d = 0.75), and the school scale (d = 0.95; Table 3). These significant differences indicated that adolescents with an FGID reported lower quality of life compared to their same-aged peers on multiple domains. The difference between groups was not significant for the physical and emotional subscale of the QoL measure. Regarding affect

there was a significant difference and large effect size between groups for positive affect (*d* = 0.74). These results indicated that adolescents with an FGID reported less positive affect over the study period. The difference between groups was not significant for sleep duration or negative affect.

Table 3

Analysis of Variance between adolescents with and without FGIDs

Measure	Sum of Squares	df	Mean Square	F	Sig
QoL Total					
Between Groups	813.24	1	813.24	**5.62**	**.022**
Within Groups	6804.79	47	144.78		
Total	7618.04	48			
QoL Physical					
Between Groups	327.53	1	327.53	1.71	.197
Within Groups	8990.87	47	191.30		
Total	9318.40	48			
QoL Emotional					
Between Groups	2403.57	1	2403.57	.001	.973
Within Groups	16521.81	47	351.53		
Total	18925.38	48			
QoL Social					
Between Groups	3217.69	1	3217.69	**6.84**	**.012**
Within Groups	13594.56	47	289.25		
Total	16812.25	48			
QoL School					
Between Groups	1184.01	1	1184.01	**11.12**	**.002**
Within Groups	8337.67	47	177.40		
Total	9521.68	48			
QoL Psychosocial					
Between Groups	0.34	1	0.34	**6.67**	**.013**
Within Groups	14233.33	47	302.84		
Total	14233.67	48			
Positive Affect					
Between Groups	36.34	1	36.34	**8.58**	**.005**
Within Groups	203.332	48	4.24		
Total	239.674	49			
Negative Affect					
Between Groups	1.31	1	1.31	.68	.415
Within Groups	93.21	48	1.94		
Total	94.53	49			
Total Sleep Time					
Between Groups	8778.16	1	8778.16	3.85	.056
Within Groups	109549.21	48	2282.28		
Total	118327.36	49			

Aim 2: The differential association between negative affect and sleep duration in adolescents with an FIGD and their same-aged peers was examined with group status acting as the moderator.

TST as the dependent variable. First, the model with TST as the dependent variable was examined. The ICC for TST was .148 indicating that 14.8% of the variability was between-person, and that 85.2% of the variability was within-person. After four separate models of time were compared for TST, a random linear effect of time was established for this variable. This indicated that TST randomly increases or decreases in a linear fashion across the study period for this sample. Results of the multilevel models indicated there was a significant random effect for negative affect [95% CI = (-48.96, 614.42)] and positive affect [95% CI = (-36.87, 379.52)] prospectively associated with TST. Further, TST was positively associated with group status (β = 37.03, $p < .05$), such that community adolescents obtained longer sleep duration than the adolescents with an FGID.

The model for TST revealed a significant 3-way interaction between weekday, group status, and negative affect ($\beta = 21.60$, $p < .05$; Figure 2). Probing this significant interaction to interpret the conditional effects indicated that when negative affect is one standard deviation below the child's own average on weekends, participants in the FGID group obtained significantly more sleep than those in the comparison group ($\beta = 47.67$, $p < .05$; Figure 3). The remaining simple slopes of this interaction were non-significant.

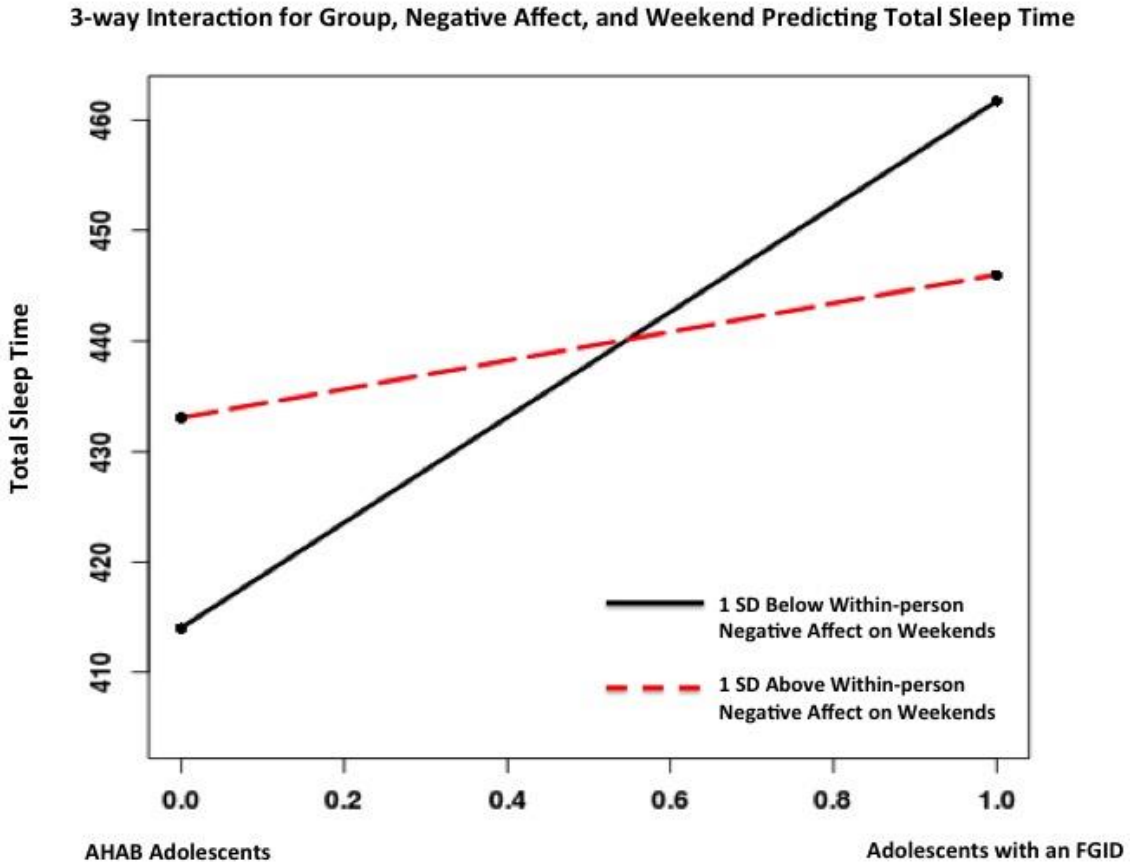

Figure 2. 3-Way Interaction for Group, Negative Affect, and Weekend Predicting Total Sleep Time. *Note*: SD= Standard Deviation

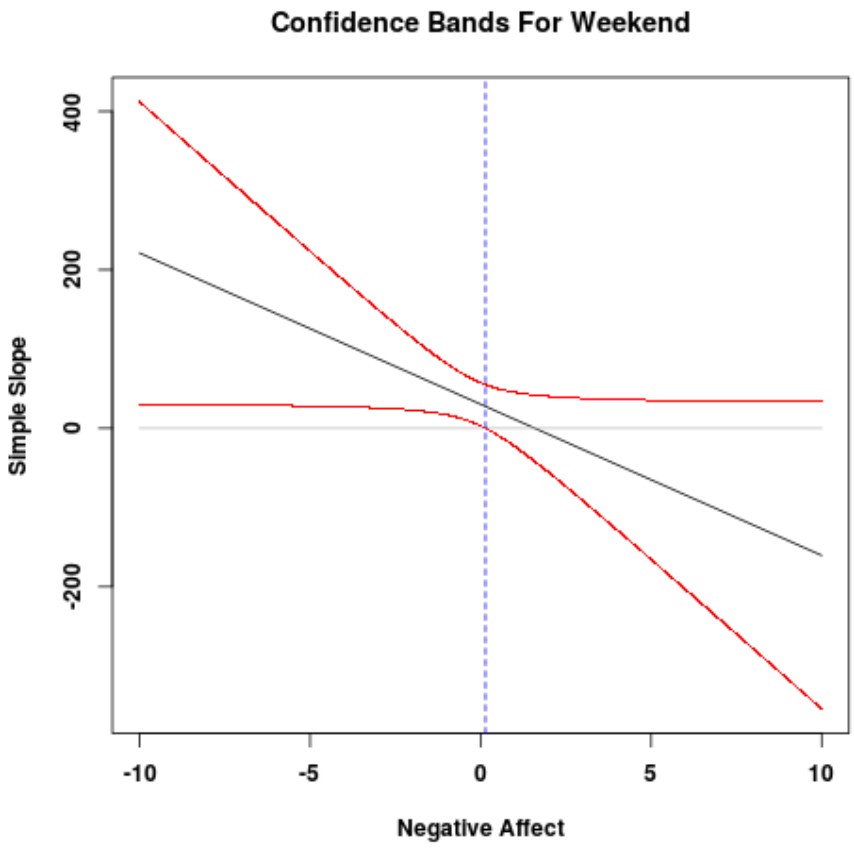

Figure 3. Plot illustrating confidence bands for observed sample values of negative affect. *Note*: Simple slopes are significant outside of 0.14 to 1202.68 bounds.

Negative affect as the dependent variable. Next, the model with negative affect as the dependent variable was examined. The ICC for negative affect was .629 indicating that 62.9% of the variability was between-person, and that 37.1% of the variability was within-person. A random linear effect of time was established for negative affect, indicating that this variable randomly increases or decreases in a linear fashion across the study period for this sample. Results of the multilevel models indicated there was a significant random effect for TST [95% CI = (-0.006, 0.005)] prospectively associated with negative affect. Further, the interaction term

of within-person TST was positivity associated with negative affect when group status was entered as a moderator (β = .003, $p < .05$). Probing this significant interaction to interpret the conditional effects resulted in non-significant simple slopes.

Aim 3: The differential association between positive affect and sleep duration in adolescents with an FIGD and their same-aged peers was examined with group status acting as the moderator.

TST as the dependent variable. First, the model with TST as the dependent variable was examined. As mentioned previously, results of the multilevel models indicated there was a significant random effect for negative affect [95% CI = (-48.96, 614.42)] and positive affect [95% CI = (-36.87, 379.52)] prospectively associated with TST. Further, TST was positively associated with group status (β = 34.59, $p < .05$), such that community adolescents obtained longer sleep duration than the adolescents with FGIDs. There were no significant interactions in this model.

Positive affect as the dependent variable. Next, the model with positive affect as the dependent variable was examined. The ICC for positive affect was .736 indicating that 73.6% of the variability was between-person and 26.4% of the variability was within-person. A random linear effect of time was established for positive affect, indicating that this variable randomly increases or decreases in a linear fashion across the study period for this sample. Results of the multilevel models indicated there was a significant random effect for TST [95% CI = (-0.01, 0.01)] prospectively associated with positive affect. No other significant associations or interactions were found in the model of sleep duration predicting positive affect.

Table 4

Associations of Predictors and Covariates with TST as the dependent variable

	TST	
	β (SE)	*p*
Positive Affect		
Fixed Effects		
Intercept	421.79 (15.31)	<.0001
Time	0.55 (0.36)	.13
BP	-2.53 (2.11)	.24
WP	-2.73 (5.27)	.61
Group	**34.59 (11.66)**	**.004**
Weekday	-4.49 (5.70)	.43
WP PA*Weekday	5.21 (4.32)	.23
WP PA*Group	-3.55 (7.52)	.64
WP PA*Weekday*Group	-3.05 (6.21)	.62
Random Effects		
Intercept Variance	2068.40 (581.78)	.0002
Time Slope Variance	5.45 (1.50)	.0001
Intercept-Time Slope Covariance	-80.82 (26.26)	.002
Residual	5684.38 (177.09)	<.0001
Negative Affect		
Fixed Effects		
Intercept	421.76 (15.59)	<.0001
Time	.54 (.37)	.15
BP	-1.95 (3.11)	.53
WP	10.95 (7.64)	.16
Group	**37.03 (11.33)**	**.002**
Weekday	-4.78 (5.70)	.40
WP NA*Weekday	**-17.39 (6.49)**	**.007**
WP NA*Group	-18.01 (9.99)	.08
WP NA*Weekday*Group	**21.60 (8.06)**	**.007**
Random Effects		
Intercept Variance	2263.69 (622.69)	.0001
Time Slope Variance	5.63 (1.53)	.0001
Intercept-Time Slope Covariance	-86.69 (27.47)	.002
Residual	5659.22 (176.45)	<.0001

Note: TST= Total Sleep Time, PA= Positive Affect, NA= Negative Affect, BP= Between person, WP= Within-person

Table 5

Association of Predictors and Covariates with Affect as the Dependent Variable

	Positive Affect		Negative Affect	
	β (SE)	*p*	β (SE)	*p*
TST				
Fixed Effects				
Intercept	7.67 (2.49)	.003	2.89 (1.59)	.07
Time	-0.01 (.007)	.16	.000 (.006)	.99
BP	-0.004 (.006)	.48	–0.004(.004)	.33
WP	-0.001 (.001)	.29	-0.001(.001)	.14
Group	-1.07 (.62)	.09	.04 (.40)	.91
Weekday	-.13 (.08)	.09	-.02 (.06)	.98
WP TST*Weekday	-.0002 (.001)	.84	-.02 (.001)	.18
WP TST*Group	.001 (.002)	.61	**.003 (.001)**	**.02**
WP TST*Weekday*Group	.000 (.001)	.97	-.002 (.001)	.09
Random Effects				
Intercept Variance	5.11 (1.08)	<.0001	2.73 (.58)	<.0001
Time Slope Variance	.002 (.001)	<.0001	.002 (.0003)	<.0001
Intercept-Time Slope Covariance	-.04 (.02)	.02	-.04 (.01)	.001
Residual	1.15 (.03)	<.0001	0.69 (.02)	<.0001

Note: TST= Total Sleep Time, BP= Between person, WP= Within-perso

Discussion

The present study aimed to determine whether there is a differential association between affect and sleep in adolescents with and without FGIDs. The first hypothesis of the first aim was supported, such that adolescents with FGIDs reported lower overall, psychosocial, social, and school QoL than their same-aged peers. The current study found similar results to Varni et al., (2015) who indicated youth with FGIDs report significantly lower QoL on the total score, and each subscale, of the PedsQL compared to healthy controls. The current study, however, did not observe the same difference for the physical and emotional subscale of the PedsQL. The community adolescents in the present study reported lower emotional and physical QoL than other published healthy control samples, by approximately one standard deviation (Varni et al., 2015; Youssef et al., 2006). In addition, youth with FGIDs in the current study also reported lower positive affect than their same-aged peers, supporting the third hypothesis of the first aim. This finding is unsurprising since a positive relationship between positive affect and health related quality of life has been observed in samples with other chronic health conditions (Spindler, Denollet, Kruse, & Pedersen, 2009), and individuals with chronic pain typically report lower levels of positive affect (Pressman & Cohen, 2005).

The hypothesis of the second aim was partially supported with results indicating that adolescents with FGIDs obtained significantly less sleep, compared to their healthy peers. This finding is consistent with previous studies regarding youth with chronic pain. When sleep is measured objectively through repeated measurement, youth with chronic pain demonstrate more sleep disruptions, and shorter sleep durations compared to healthy peers (Lewandowski, Palermo, De la Motte, & Fu, 2010; Palermo et al., 2007). Although there was not a significant difference between the FGID group and the community sample when comparing their between-person average TST in Aim 1, the adolescents with chronic abdominal pain demonstrate lower

sleep durations when the analysis is conducted as a multi-level model utilizing nested data in Aim 2. The TST variable was measured repeatedly, across 14 days, however in Aim 1, the TST values were averaged across time for each participant and then analyzed to conduct the between person analysis. In Aim 2 however, TST was not averaged over the study period and the night-to-night variation in TST was retained. Different relationships are to be expected at different levels of analysis because these relationships reflect different phenomena at each level of analysis. The TST for adolescents with an FGID in Table 2 shows a wider range and larger standard deviation than the TST for the community adolescents, indicating the youth with FGIDs had more TST variability.

Inconsistent with the hypothesis of Aim 2, however, there was not a significant interaction between negative affect predicting TST when group status was included as the sole moderator. This model did not differentiate between weekdays and weekend days, which is an important distinction to make because adolescents have been known to obtain almost two additional hours of sleep on the weekend (Wolfson & Carskadon, 1998), and adolescents who sleep less on weekdays experience elevated emotional and behavioral problems during the day (O'Brien & Mindell, 2005). To address this concern, an additional dichotomous moderator (i.e., weekday/weekend) was added to the model examining the interaction between negative affect predicting TST with group status to account for differences in TST and negative affect on weekdays and weekends.

There was a significant three-way interaction, when the dichotomous weekday/weekend variable was added as an additional moderator, providing partial support for the hypothesis of Aim 2. These results revealed that adolescents with FGIDs obtain significantly more sleep on the weekends when they are experiencing negative affect one standard deviation below their mean,

compared to their healthy peers. This finding aligns with youth sleep research such that when a child's mood is worse than their typical mood, their sleep duration (Tavernier, Choo, Grant, & Adam, 2016) and sleep quality (i.e., fragmentation and longer latency) can be negatively affected (Kouros & El-Sheikh, 2015). Further, fewer demands are placed on children and adolescents on the weekend, and school schedules have been shown to have significant effects on sleep behaviors during the week (Adam, Snell, & Pendry, 2007). This is particularly important within a biopsychosocial framework, because the influence of emotional distress on biological functioning may differ across settings (i.e., school and home) and contexts (i.e., situtaions that elecit either high postive or negtaive affect; Segal-Andrews et al., 1995). The adolescents with FGIDs in the present study reported significantly lower quality of life on both the psychosocial and school subscales, indicating emotional distress may be elevated on weekdays. The findings of the present study show that when adolescents with FGIDs have lower emotional distress, or negative affect, on the weekend when demands are reduced, they are able to obtain longer sleep durations.

The relationship between TST and negative affect was tested bidirectionally, and group membership was found to moderate the relationship between sleep duration predicting negative affect. Interestingly, the results of probing the conditional values yielded non-significant simple slopes. This finding is important for youth with FGIDs since sleep impacts bio-behavioral and restorative processes, which regulate daily emotional experiences and emotional stress (Vandekerckhove & Cluydts, 2010). Sleep disruptions lead to difficulty regulating negative emotions (Dahl & Lewin, 2002) because emotional experiences are consolidated throughout the night, and sleep duration and quality is closely tied to emotional reactivity the following day (Walker & van Der Helm, 2009). In a study by Baum et al. (2014) adolescents who experienced

a 20% reduction in sleep duration reported increased levels of tension, anxiety, anger, and irritability. The adolescents in the Baum et al. (2014) study, however, demonstrated high variability on measures of mood and emotional regulation. The participants in the present study demonstrated a restricted range and low variance in their negative affect responses. The null finding observed for TST predicting negative affect is likely due to a floor effect in the measurement of negative affect. Further, while many studies have demonstrated a connection between sleep and affect (i.e., measured via the Profile of Mood States or PANAS; Fuligni & Hardway, 2006), sleep is typically experimentally restricted by 50-60% in these studies, causing participants to experience significant sleep loss (Franzen et al., 2008; Talbot et al., 2010). The adolescents in this study were, on average, getting seven hours of sleep during the study period, which falls just short of the recommended eight hours by the American Academy of Sleep Medicine (Paruthi et al., 2016). Although the participants in the present study were not meeting the recommended amount of sleep overall, they may not have experienced continuous sleep restriction to the degree necessary to detect a significant relationship between sleep duration and negative affect.

The third aim examined the differential association between positive affect and TST in adolescents with an FGID and their same aged-peers with group status acting as the moderator. The hypothesis was unsupported such that there was no moderating effect of group membership in the relationship between positive affect and TST. Further, the inclusion of the dichotomous weekday/weekend variable as an additional moderator did not yield significant results. Positive affect is linked to better sleep behaviors (i.e., better sleep quality, fewer disturbances) in the general population (Delannoy, Mandai, Honore, Kobayashi, & Sequeira, 2015; Steptoe, Dockray, & Wardle, 2010); however, little evidence has been provided regarding this

relationship in adolescents with FGIDs. Since adolescents with FGIDs experience more disruptions to their sleep than peers (Haim et al., 2004; Huntley et al., 2007), a group difference between positive affect and sleep duration was expected. While sleep duration is a common variable used when examining sleep behavior, this only provides the length of time one is asleep and does not provide information regarding sleep architecture. Methods that use polysomnography are able to measure rapid eye movement (REM) sleep, which facilitates emotion processing and recovery from negative emotion (Riemann et al., 2012; Walker & van Der Helm, 2009) and may be more appropriate to use when examining positive affect. Future studies may wish to assess the length of time participants are in each stage of sleep to examine how sleep architecture impacts within-person positive affect.

Limitations

The research team decided to omit a sleep log in order to reduce participant burden and increase participant adherence to the study protocol. This additional measure is typically included when sleep is measured objectively in the participant's free-living environment to verify the sleep data in the event that a long period of immobility is classified as a sleep period (Sadeh, 2008). Existing sleep measurement recommendations suggest using a sleep log in conjunction with an accelerometer (Meltzer, Montgomery-Downs, Insana, & Walsh, 2012). The research teams at the University of Kansas and Children's Mercy Hospital, however, decided to prioritize reducing participant burden since the assessment of sleep behaviors were a secondary aim of the larger AHAB and Precision Medicine in Pediatric FGIDs studies. The algorithm utilized in the present study detects a period of prolonged sleep and calculates the TST based on the information obtained within that sleep period. Minimal error is to be expected, however, error can be introduced if there is significant movement throughout the night or if the device falls

off during the night. When a sleep log is included alongside an accelerometer, participants can indicate their bedtime and wake time each day they wore the accelerometer, and the researcher can verify the participant's sleep data for obvious outliers.

Additionally, the current study focused on affect and did not include a measure of physiological arousal (i.e., heart rate) or energy and fatigue levels. While these additional measures were outside the scope of the present study, arousal and energy and fatigue are important components to the study emotions. Physiological arousal has been found to impact sleep latency in adolescents (Dahl & Lewin, 2002) and arousal regulation can be variable during this developmental period. Further, some research suggests that memories are encoded and preserved in a more stable state if the individual perceives a high energetic state (Kensinger, 2004). Studies that include EMA surveys regarding emotional valance and energy and fatigue, or additional devices such as heart rate monitors, may better characterize the relationship between emotions and health behaviors (e.g., Cushing, Mitchell, Bejarano, Walters, & Noser, 2017).

Another limitation to the present study is the exclusion of a daily pain assessment for the community sample. Due to this aspect, the researchers are unable to conclude whether the differences found in the results are directly related to, or driven by, the experience of abdominal pain. FGIDs entail a complex etiology that may have introduced confounding variables into the results. Further, the community adolescents could have experienced some form of abdominal pain while in the study, thus impacting the ability to determine a group effect.

The present study did not include the number of missed school days for the participants in the sample, and thus is a limitation to the results. The QoL measure did include two questions on the school subscale regarding missed school days (e.g., "I miss school because of not feeling well" and "I miss school to go to the doctor or hospital"). Further, there was a significant

difference between groups, such that the FGID group reported lower QoL on these two items. While the school subscale is correlated with school absenteeism (Varni, Seid, & Kurtin, 2001), these specific items only ask participants to report how much of a problem this has been over the previous month, and does not provide specific information regarding the days the adolescents participated in the study. The present study did not include records of school attendance or ask participants to self-report missed school days. Future research may consider the addition of these measures to account for observed variability due to these confounds.

Lastly, there are limits to the generalizability of the present study's findings due to the homogeneity of the sample. Efforts were made to recruit a diverse sample of adolescents with respect to gender, race, and family socioeconomic status. The study sample, however, was predominantly Caucasian, female, and upper middle class, which is reflective of the population demographic in each recruitment setting.

Clinical Implications

The support for negative affect as a predictor of sleep duration has clinical implications for adolescent psychological and physical health. Adolescents with FGIDs that experience high negative affect may be vulnerable to short sleep durations. Findings from this study could help inform interventions targeting sleep behaviors to improve sleep quality and, in turn, lead to clinical improvement in quality of life. Through these interventions, it may be beneficial for adolescents with FGIDs to learn coping strategies that may lower their negative affect. If adolescents can lower their negative affect by one standard deviation, then they may be able to increase their sleep duration throughout the night. There is currently a lack of clinical practice guidelines for adolescents with FGIDs and results from this study may inform future treatment recommendations for adolescents who exhibit high negative affect or experience short sleep

durations. Future recommendations may specify education regarding sleep hygiene to increase sleep duration and increasing coping strategies (e.g., relaxation, thought challenging and replacement, behavioral activation) to reduce negative affect.

Conclusions and Future Directions

The present study provides knowledge regarding the relationship between within-person negative affect and sleep duration in adolescents with and without FGIDs. Future studies may examine fluctuations in affect by testing whether it changes at different times of day or in relation to an individual's daily emotional experiences. Future studies may also consider examining daytime predictors in relation to nighttime awakening in chronic abdominal pain populations to better understand the role of sleep disturbances. It would be informative to also examine daytime fluctuations in adolescent fatigue and energy levels as it related to affect and sleep duration. Fatigue has been shown to mediate the relationship between sleep and positive and negative affect (Bouwmans, Bos, Hoenders, Oldehinkel, & de Jonge, 2017). Since adolescents with chronic pain frequently experience fatigue (Gold, Mahrer, & Palermo, 2009), this mediator may have important implications for adolescents with FGIDs who are not meeting sleep recommendations and experience difficulties with affect.

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